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A VEGETATION AND FLORISTIC ANALYSIS OF A CREATED WETLAND IN SOUTHEASTERN NEW HAMPSHIRE

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ABSTRACT

The artificial creation of wetlands has become a common means to mitigate the effects of wetland alteration due to development. The establishment of diverse, functional plant communities is a crucial and challenging part of a wetland creation project. This study analyzes plant community structure of a seven year old, artificially created wetland. One hundred and four vascular plant species are documented from the study site including two species listed as rare for New Hampshire and the first state record for an introduced weedy species.

The computer program TWINSPAN used species abundance data to classify the vegetation into seven cover types. The three plant associations of the open water habitat were: *Chara* cover type, *Potamogeton pusillus* cover type, and the *Potamogeton natans* cover type. The four plant associations of the emergent habitat were: *Eleocharis smallii* cover type, *Typha latifolia* cover type, *Juncus effusus-Phalaris arundinacea* cover type, and a *Carex stricta* cover type. Each cover type and associated habitat was described and delineated.

Key Words: floristics, wetlands, wetland mitigation, rare plants

INTRODUCTION

Encompassing such diverse systems as freshwater marshes, swamps, bogs, sloughs, ponds and lakes, rivers and streams, coastal freshwater tidal marshes, and saltmarshes, wetlands collectively constitute one of the most productive biomes on Earth (Good et al., 1978; Mitsch and Gosselink, 1986). Beyond the obvious aquatic productivity and associated food-chain support, wetland ecosystems are vital in performing numerous other ecological functions (Goodwin and Niering, 1974; Burke et al., 1988; Larson, 1988). The rather late recognition of wetland values and functions over the past two decades seems to have been catalyzed by the alarming

rate at which wetlands are being destroyed. Most important, the vital role wetlands play in the overall quality of the environment has finally been recognized and a variety of efforts are being implemented to provide a means for their conservation.

One strategy that has been developed to conserve wetlands is termed wetland mitigation. Wetland mitigation reduces or compensates for the negative impacts on aquatic ecosystems imposed by development by artificially creating or restoring wetland areas (Savage, 1986). Mitigation has become an integral part of wetland protection and conservation policies. Wetland mitigation attempts to restore to an area those functions of a wetland that are impacted or destroyed.

The primary goal of wetland creation or restoration projects typically aims at restoring lost wetland functions. Wetland creation efforts additionally aim at creating an area that is at least the same size as the area lost and the establishment of certain wetland vegetation types (Lowry, 1990; Kruczynski, 1990).

The establishment of hydrophilic vegetation is crucial in wetland mitigation projects if they are to imitate successfully natural wetland ecosystems. Wetland vegetation provides some of the important functions and values inherent in wetlands (Good et al., 1978; Mitsch and Gosselink, 1986) and creates suitable habitats for wildlife (Weller, 1978). The establishment of diverse, functional wetland plant communities is a challenging part of mitigation projects (Padgett and Crow, in press).

The objective of the present study is to provide a detailed vegetation analysis and total floristic inventory of a seven year old, artificially created, freshwater wetland located in southeastern New Hampshire.

Site History

During the winter of 1985–86, the Hospital Corporation of America (HCA) created a freshwater wetland under the Section 404 guidelines of the U.S. Army Corps of Engineers to compensate for the filling of a wetland at the construction site of a new regional hospital in Portsmouth, New Hampshire. The land area designated for the creation of the compensatory wetland was an abandoned gravel pit located approximately 3 miles from the hospital site in the southern end of Portsmouth, NH (Rockingham Co.) (Michener et al., 1986). The size of the mitigation area (ca. 13

acres) was similar to the size of the area lost due to the hospital construction.

Wetland construction began in the fall of 1985 and continued through the winter of 1986. Basins were excavated and graded to form a sinuous configuration of open water pools and marsh areas (Michener et al., 1986). The wetland soils and peat at the new hospital site (impacted wetland) were excavated and transported to the new wetland creation site. This material was stockpiled through the winter and eventually spread as a 6–12″ top dressing over the excavated basins.

The primary strategy to vegetate the newly created basins was to allow for the natural colonization of wetland plants. Therefore there was no direct planting of wetland plant stock. The muck top dressing was expected to serve as a created "seed bank" naturally holding large quantities of plant seeds and vegetative propagules (Michener et al., 1986).

Groundwater is the primary hydrological input into the site. Groundwater flow is westward, discharging into the adjacent forested swamp (Garlo, 1993). However, during the first summer after construction, beavers dammed the small outflow channel. Consequently, the water level was raised approximately two feet above the design elevation.

Site Description

The H.C.A. Portsmouth wetland is a created freshwater wetland consisting of primarily herbaceous aquatic plants. Some tree and shrub areas exist on several upland islands and pool margins. Open water areas form sinuous configurations around these islands. The maximum depth of the open water areas is approximately two meters. The created wetland is surrounded by upland forest communities on the northeastern and southern sides, and a wetland forest community on the northwestern side. A disturbed, open, sandy area with few woody plants surrounds the wetland on the southeast side.

MATERIALS AND METHODS

Vegetation Analysis

Vegetation data were collected during July of 1992. Sampling was done using a systematic sampling method (Mueller-Dombois

and Ellenberg, 1974). Thirteen transects were established across the wetland at 20 meter intervals. A single 0.5 × 0.5 m quadrat was placed at every five meters of transect for a total of 284 sample plots. Trees, shrubs and herbs occurring on the banks and upland sites on the islands throughout the wetland were not included in the sampling.

A visual estimate of percent cover was recorded to estimate abundance. The primary focus of the vegetation analysis was vascular plant species. However, because of their relative abundance *Chara* cf. *vulgaris* and *Ricciocarpus natans,* two non-vascular aquatic plants, were included in the vegetation analysis. Cover was defined as the vertical crown or shoot-area projection per species in relation to the reference area (Mueller-Dombois and Ellenberg, 1974).

The data were analyzed using TWINSPAN (Two-Way Indicator Species Analysis), a fortran classification analysis program. The program first constructs a classification of samples and then based on this classification, constructs a classification of species according to their ecological preferences (Hill, 1979).

TWINSPAN groups the quadrat samples according to the floristic similarity of its members. Using these groups as a basis, species are clustered to form hierarchial dichotomies. There are three ordinations involved in determining a dichotomy: 1) a primary ordination, made by a method of reciprocal averaging; 2) a refined ordination, using differential species determined from the primary ordination; and 3) an indicator ordination, using highly preferential species (Hill, 1979). Corresponding to the Braun-Blanquet cover-abundance scale of 0, 5, 25, 50 and 75 percent (Mueller-Dombois and Ellenberg, 1974), abundance data of TWINSPAN "pseudo-species" were classified at cut levels of 1, 2, 3, 4 and 5 respectively. Ultimately, a two-way table is generated grouping similar quadrat samples across the top and similar species down the left side (Padgett, 1993).

A vegetation map (Figure 2) was prepared based on cover types of quadrats along the 13 transects to give a visual estimate of the pattern of distribution of the seven cover types.

Floristic Study

An inventory of the vascular plants of the site was undertaken during the 1992 field season. Voucher specimens were collected

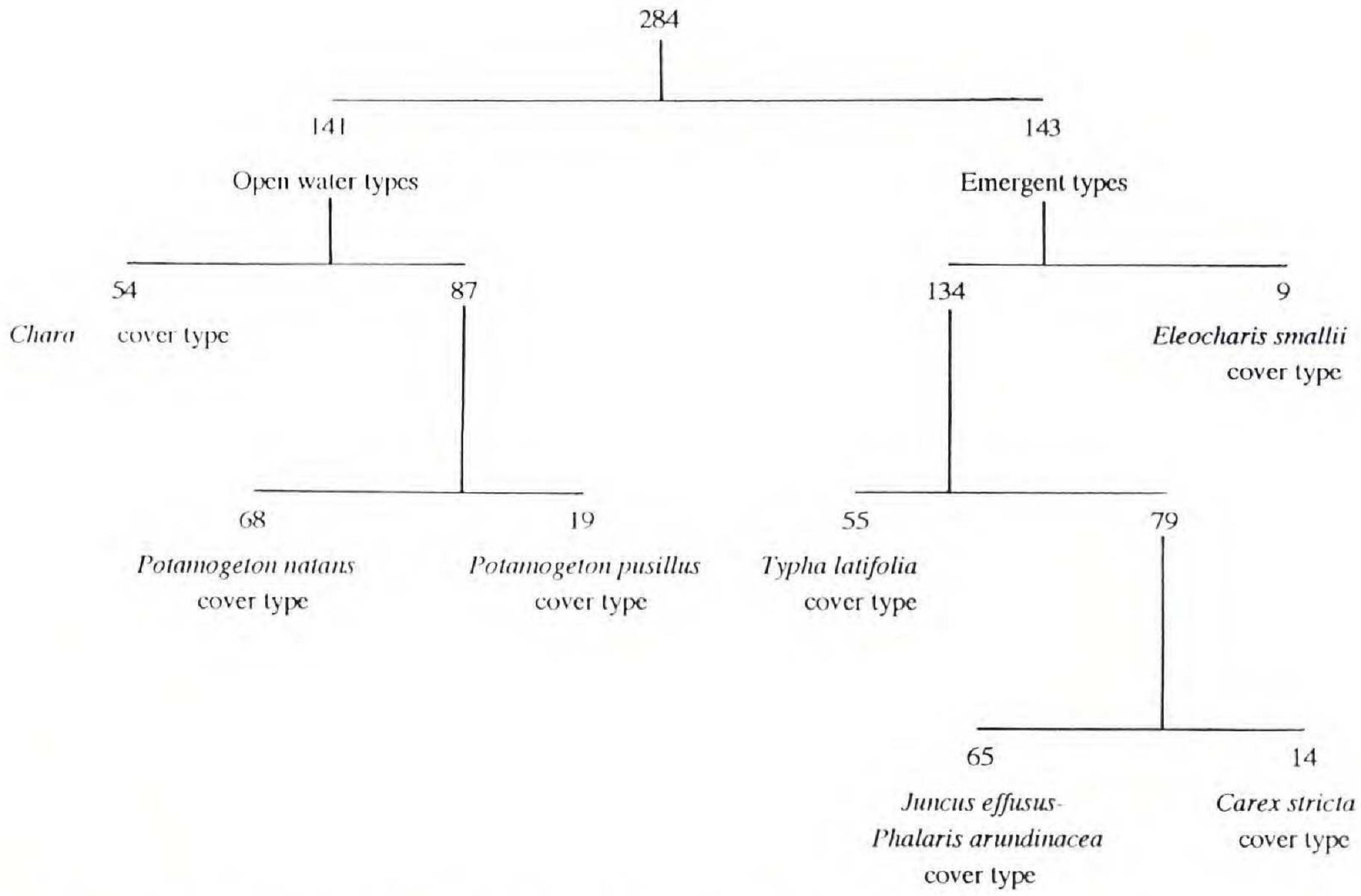

Figure 1. TWINSPAN analysis showing the seven plant cover types classified at four hierarchical levels. Numerals represent the number of quadrats included in each dichotomy.

and deposited in the Hodgdon Herbarium (NHA) at the University of New Hampshire.

Nomenclature follows *Aquatic and Wetland Plants of Northeastern North America* (Crow and Hellquist, in press) and *Manual of Vascular Plants of Northeastern United States and Adjacent Canada* (Gleason and Cronquist, 1991).

RESULTS AND DISCUSSION

The construction of the H.C.A. Portsmouth wetland has created a unique environment, allowing for a natural colonization and emergence of wetland plant species. The various micro-habitats formed by the gradual slopes of the basins and integration of raised islands provide a heterogeneous ecosystem. As a result, concentric vegetation zones have developed according to the ecological affinities of species characteristic of natural wetland systems. The vegetation patterns of the site are typical of those described for inland freshwater wetlands (Mitsch and Gosselink, 1986; Hammer, 1992; Weller, 1978; Curtis, 1959). Generally, for most inland wetlands, sedges (*Carex*) and rushes (*Juncus*) occupy

the wet-meadow areas gradually passing into the shallow water areas colonized by Cattails (*Typha*), Bulrush (*Scirpus*) and Pickerel Weed (*Pontederia cordata*). The deeper, open water areas are colonized by submerged species (*Utricularia*) and floating leaved species (*Potamogeton* and *Nuphar*).

Plant Cover Types

The wetland vegetation was classified using TWINSPAN into seven cover types (Figure 1). Data from 284 quadrats were analyzed and 67 species were clustered at four hierarchical divisions into the seven cover types which could be visually recognized in the field.

The first dichotomy grouped the 284 quadrats into two major groupings, with 141 quadrats representing the open water cover types, and 143 quadrats representing the emergent cover types. At the second level of clustering, 54 quadrats of open water types were distinguished as the *Chara* cover type, with 87 quadrats remaining to be sub-clustered. At the third level 68 quadrats represented the *Potamogeton natans* cover type and 19 quadrats defined the *Potamogeton pusillus* cover type.

TWINSPAN grouped the 143 quadrats in the emergent cover type group into four cover types (Figure 1). At the second level the *Eleocharis smallii* cover type was recognized (9 quadrats). At the third level the *Typha latifolia* cover type was distinguished (55 quadrats), while the *Juncus effusus-Phalaris arundinacea* (65 quadrats) and *Carex stricta* (14 quadrats) cover types were not defined until the fourth level.

The clustering of the quadrats at the first divisional level clearly correlates with the two primary habitats designed for the site creation. The open water cover types occupy the areas where the water is too deep to be colonized by emergent species. Most of the open water areas were vegetated by floating-leaved, free-floating and submerged species. However, some areas remained devoid of vascular plants. For instance, one open pool was heavily colonized by filamentous algae. Although three cover types were recognized as the open water areas, these were not characterized by distinct vegetation zones. Instead these cover types occurred in a mosaic pattern.

The emergent cover types represent the marsh or wet meadow regions designed for the wetland. These areas are defined by a

topographic gradient beginning in the shallow fringe areas of the open pools and extending back into the higher areas of the marsh. Consequently, the emergent cover types are better characterized by zonational patterns when compared to the open water cover types. The emergent cover types are the most floristically diverse areas of the wetland and are characterized by a predominance of emergent species. However, the free-floating *Lemna minor* was found in greater frequencies and abundance within the emergent cover types than in the open water cover areas.

OPEN WATER COVER TYPES

Potamogeton natans Cover Type

The *Potamogeton natans* cover type is the largest plant association of the open water types (Figure 2), defined by the 68 quadrats clustered by TWINSPAN. Of the seventeen species that characterize the community, the floating-leaved *P. natans* is dominant with 35% cover and 90% frequency (Table 1). The submerged *Najas minor* and *Utricularia gibba* are sub-dominants with 11% and 9% covers, respectively, although *U. gibba* has a significantly higher percent frequency. The delicate morphology of *U. gibba* does not allow for high percent coverage.

The cover type is easily discernible by the presence of broad floating leaves of *Potamogeton natans* that form an expansive cover on the surface of the water. This floating-leaf layer was so extensive in certain portions of the wetland, particularly in the northwestern pool, that few open surface water areas were present. Although the cover of *P. natans* was very extensive, the mean percent cover of *P. natans* throughout the entire cover type was only 35%. In areas that were sparsely populated with *P. natans* submerged species, such as *Najas minor, Utricularia gibba* and *P. pusillus,* were frequent.

Chara Cover Type

The *Chara* cover type is one of the larger plant associations of the open water types (Figure 2). The community can be characterized by 15 species, but the macrophytic alga *Chara* cf. *vulgaris* dominates with 81% cover and 98% frequency (Table 2). Plants

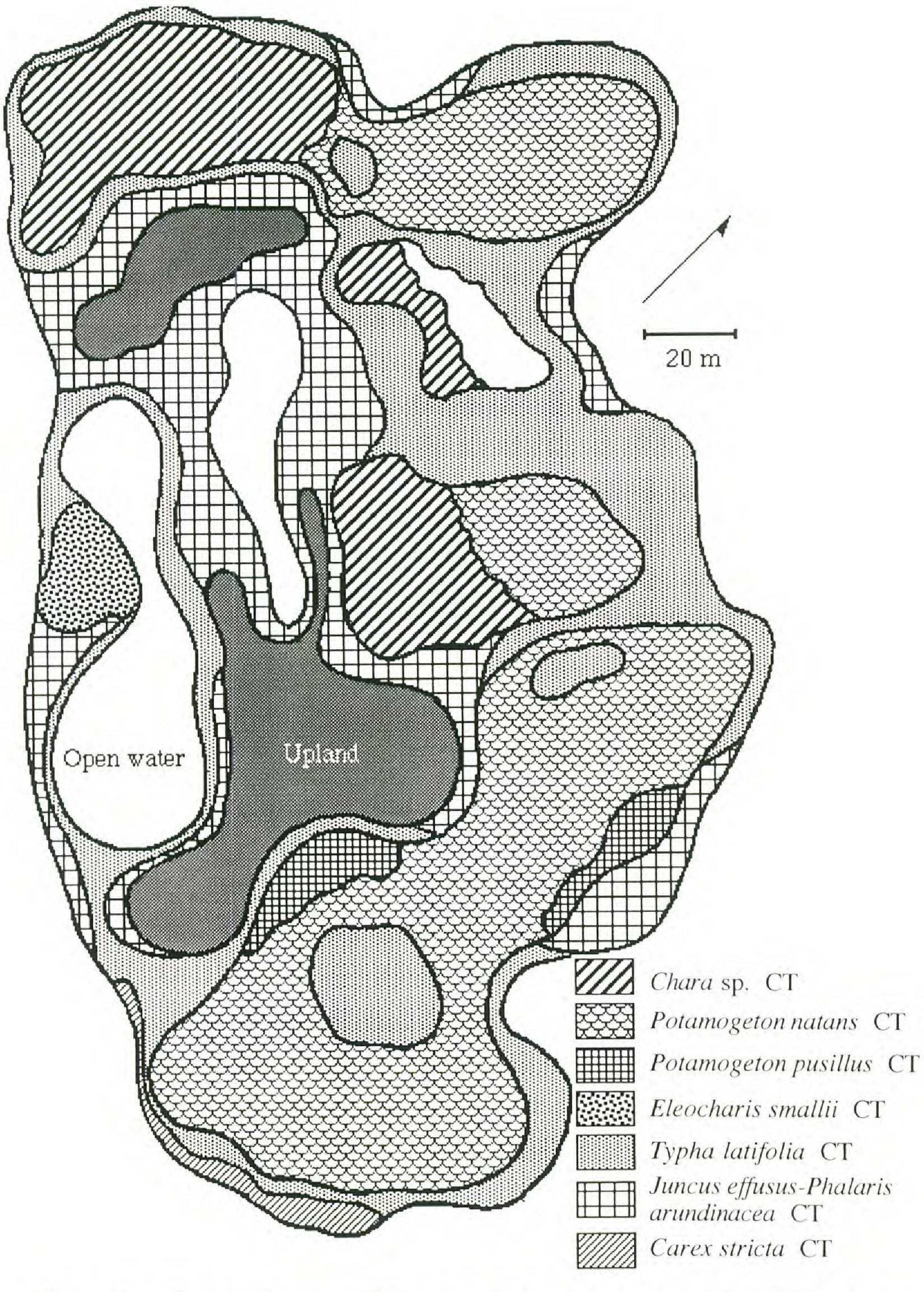

Figure 2. The distribution of the seven plant cover types of the H.C.A. Portsmouth created wetland. CT = Cover type.

Table 1. Mean percent cover and percent frequency for species in the *Potamogeton natans* cover type (species with cover <1 percent are excluded).

Species	% Cover	% Frequency
Potamogeton natans	35	90
Najas minor	11	15
Utricularia gibba	9	82
Potamogeton pusillus	2	15
Eleocharis acicularis	2	6
Lemna minor	1	19
Ludwigia palustris	1	10

of *Chara* were commonly observed as monotypic colonies or with few other species. However, *Utricularia gibba* and *Potamogeton natans* are sub-dominant components of the community. The remaining species of the community (Table 2), with the exception of *P. pusillus,* are more characteristic of emergent areas.

The weedy nature of *Chara* has allowed it to successfully colonize the open water areas of the site. More typically associated with hard water sites, *Chara* has been found to dominate deeper waters of lakes producing large amounts of biomass (Rickett, 1921). The *Chara* community exists in the deeper pools of the wetland, where the cover of floating leaved species is relatively low.

Potamogeton pusillus Cover Type

This cover type is characterized by the submerged Pondweed species, *Potamogeton pusillus* (Table 3). This plant association

Table 2. Mean percent cover and percent frequency for species in the *Chara* cover type (species with cover <1 percent are excluded).

Species	% Cover	% Frequency
Chara cf. *vulgaris*	81	98
Utricularia gibba	11	56
Potamogeton natans	9	37
Eleocharis acicularis	3	7
Ludwigia palustris	1	9
Potamogeton pusillus	1	7
Juncus articulatus	1	4
Typha latifolia	1	4

Table 3. Mean percent cover and percent frequency for species in the *Potamogeton pusillus* cover type (species with cover <1 percent are excluded).

Species	% Cover	% Frequency
Potamogeton pusillus	36	95
Pontederia cordata	12	21
Eleocharis acicularis	5	26
Potamogeton natans	4	47
Utricularia gibba	3	42
Lemna minor	1	37
Najas minor	1	11
Potamogeton amplifolius	1	5

covers the smallest portion of the open water areas and was represented by only 19 quadrats. The *Potamogeton pusillus* cover type occurs in scattered areas within the open water portions of the wetland, most typically close to the emergent vegetation cover types. Two of the largest areas where this cover type is predominate are shown in Figure 2. Although, this cover type is primarily composed of submerged and free-floating species, the emergent *Pontederia cordata* is a sub-dominant component.

EMERGENT COVER TYPES

Juncus effusus-Phalaris arundinacea Cover Type

The *Juncus effusus-Phalaris arundinacea* cover type is the most floristically diverse cover type of the entire wetland. Of the 55 species occurring in the cover type, *Juncus effusus* and *Phalaris arundinacea* are co-dominant, with a collective cover value of 41% (Table 4). This cover type generally extends from the upland shores or islands to the edge communities of the *Typha latifolia* cover type (Figure 2). However, some pool margins are directly surrounded by this cover type where *Typha* does not dominate.

The areas of the *Juncus effusus-Phalaris arundinacea* cover type are rarely inundated for any extended period of time. Most portions remain wet to damp, allowing for a wide range of wetland species to exist. This mostly low-growing, herbaceous plant community has some woody components such as *Alnus incana* ssp. *rugosa, Acer rubrum* and *Cornus* spp. occupying various portions. Unique among cover types, both annuals and perennials are well represented within this association. The Cyperaceae is best repre-

Table 4. Mean percent cover and percent frequency for species in the *Juncus effusus–Phalaris arundinacea* cover type (species with cover <1 percent are excluded).

Species	% Cover	% Frequency
Juncus effusus	21	66
Phalaris arundinacea	20	83
Typha latifolia	6	31
Scirpus cyperinus	6	22
Carex scoparia	4	28
Alnus incana ssp. *rugosa*	4	9
Eleocharis acicularis	3	14
Lemna minor	2	28
Carex lurida	2	14
Acer rubrum	2	8
Cicuta bulbifera	1	28
Galium palustre	1	20
Polygonum amphibium	1	14
Onoclea sensibilis	1	14
Carex vulpinoidea	1	14
Lythrum salicaria	1	11
Polygonum punctatum	1	11
Juncus articulatus	1	9
Typha latifolia	1	9
Ricciocarpus natans	1	8
Eleocharis obtusa	1	6
Spiraea tomentosa	1	6
Eleocharis smallii	1	5
Vaccinium macrocarpon	1	3
Cornus stolonifera	1	3
Cornus amomum	1	2
Potamogeton pusillus	1	2
Solidago rugosa	1	2
Spiraea latifolia	1	2
Thelypteris palustris	1	2

sented in this community. The *Juncus effusus-Phalaris arundinacea* cover type is similar in general physiognomy to the wet-meadow zones or sedge-meadows discussed by Mitsch and Gosselink (1986), by Hammer (1992) and by Weller (1978).

Typha latifolia Cover Type

The Common Cattail cover type represents the second largest community association of the emergent types. Of the 27 species that occur in the cover type, *Typha latifolia* is dominant repre-

Table 5. Mean percent cover and percent frequency for species in the *Typha latifolia* cover type (species with cover <1 percent are excluded).

Species	% Cover	% Frequency
Typha latifolia	25	78
Juncus effusus	6	35
Lemna minor	4	82
Phalaris arundinacea	3	18
Ludwigia palustris	2	29
Utricularia gibba	2	22
Juncus articulatus	2	5
Eleocharis acicularis	1	13
Najas minor	1	14
Acer rubrum	1	2

sented by a 25% cover (Table 5). Sub-dominant components are *Juncus effusus* and *Lemna minor* with covers of six and four percent, respectively.

Typha latifolia and *Lemna minor* have the highest frequencies of occurrence in the cover type. These two species were frequently found associated with each other throughout the wetland, usually with *L. minor* fronds stranded on the wet mud and rhizomes or floating on the still water in between the *T. latifolia* plants. In a survey of southern Wisconsin Cattail marshes, *L. minor* had a frequency of 100%, although its presence was reported as insignificant (Curtis, 1959).

The *Typha latifolia* cover type is the most easily recognizable and discernible of the emergent cover types. This cover type can be quite expansive at certain portions of the wetland, or exist as narrow bands (Figure 2). Several isolated, nearly monotypic, *Typha* "islands" are also present. The dense rhizomatous network produced by *Typha latifolia,* characteristic of the species (McNaughton, 1966), encroaches upon the deeper open water from the very shallow edges. The *Typha latifolia* cover type is similar to the *Typha*-dominated zone typical of freshwater marshes discussed by Mitsch and Gosselink (1986) and by Weller (1978).

The cover type is characterized by species of many growth forms. Important emergent species include *Typha latifolia, Juncus effusus* and *Phalaris arundinacea.* Submergent species include *Utricularia gibba* and *Najas minor,* while the free-floating *Lemna minor,* and the amphibious *Ludwigia palustris* are also components of the cover type.

Table 6. Mean percent cover and percent frequency for species in the *Carex stricta* cover type (species with cover <1 percent are excluded).

Species	% Cover	% Frequency
Carex stricta	58	100
Juncus effusus	6	64
Phalaris arundinacea	6	57
Eleocharis acicularis	6	7
Cicuta bulbifera	4	43
Typha latifolia	3	14
Galium palustre	1	21
Triadenum fraseri	1	7
Spiraea tomentosa	1	7
Typha angustifolia	1	7
Polygonum sagittatum	1	7
Carex lurida	1	7

Carex stricta Cover Type

The Tussock Sedge cover type is one of the smaller emergent plant associations of the wetland. Of the 21 species associated with this cover type *Carex stricta* is dominant, with a 58% cover (Table 6). The raised, wide-spreading tussocks formed by *C. stricta* create a unique, easily discernible cover type. The *Carex stricta* cover type is scattered throughout the wetland, occupying small areas (Figure 2).

Eleocharis smallii Cover Type

The *Eleocharis smallii* cover type occupies the smallest area in the wetland (Figure 2). The cover type was defined by TWINSPAN by the clustering of only nine quadrats and includes 14 species. The dominant species is *E. smallii,* with 27% cover (Table 7). Sub-dominant species are *Typha angustifolia* and *Eleocharis acicularis.* This cover type is scattered throughout the northern portions of the emergent wetland and is also represented by small discontinuous areas intermixed with the *Typha latifolia* and *Juncus effusus-Phalaris arundinacea* cover types.

This cover type is the most floristically unique portion of the wetland. Species typically associated with peatlands, such as *Drosera intermedia, Vaccinium macrocarpon* and *Sphagnum* sp. are part of this community. *Dulichium arundinaceum* and *Viola lanceolata,* also components of the community, were not observed

Table 7. Mean percent cover and mean frequency for species in the *Eleocharis smallii* cover type (species with cover <1 percent are excluded).

Species	% Cover	% Frequency
Eleocharis smallii	27	67
Typha angustifolia	23	56
Eleocharis acicularis	12	22
Vaccinium macrocarpon	9	11
Triadenum fraseri	4	56
Asclepias incarnata	2	11
Lysimachia terrestris	1	33
Lemna minor	1	33
Spiraea tomentosa	1	22
Lythrum salicaria	1	11

growing anywhere else in the wetland. Other species common to this portion of the wetland but observed infrequently elsewhere, are *Asclepias incarnata, Triadenum fraseri, Bidens frondosa* and *Aster racemosus.* The soil of the area is very peaty and is slightly inundated in spring and early summer, but as water table drops later in the summer it becomes merely damp.

RARE PLANT DOCUMENTATION

Two plants listed by Storks and Crow (1978) and the New Hampshire Natural Heritage Inventory (DRED, 1987) as rare for New Hampshire occur at the H.C.A. created wetland, *Sparganium eurycarpum* (threatened) and *Potamogeton foliosus* (endangered). The occurrence of a third, non-indigenous species, *Najas minor,* constitutes the first record of this plant in New Hampshire. Although rare in New Hampshire, both *Sparganium eurycarpum* and *Potamogeton foliosus* are widely distributed throughout the United States (Crow and Hellquist, in press). Both species represent new records for the city of Portsmouth.

Sparganium eurycarpum (Giant Bur-reed) is reported as common along the coastal plain and in western portions of New England (Crow and Hellquist, 1981). There are currently seven documented stations for *Sparganium eurycarpum* in New Hampshire (Natural Heritage Program, pers. comm.). In a study of the rare plants of coastal New Hampshire, *S. eurycarpum* was reported from the towns of New Castle, Rye and Hampton (Dunlop and Crow, 1985). In the study site, *S. eurycarpum* occurs in shallow

water areas along the edges of the pools. The plant was more common along the western edge of the wetland. The water level of this area dropped greatly later in the growing season, leaving the plants growing in damp soils.

In New England *Potamogeton foliosus* (Leafy Pondweed) is reported as being common in calcareous waters of northeastern Maine, Vermont, western Massachusetts and Connecticut (Hellquist and Crow, 1980). Storks and Crow (1978) reported that *P. foliosus* was known from a single station in New Hampshire, in the town of Columbia, Coos County. There are currently five known stations of *P. foliosus* in New Hampshire (Natural Heritage Program, pers. comm.). *Potamogeton foliosus* occurs in the open water areas of the study site. Plants were intermixed with the very similar looking *P. pusillus,* therefore the exact extent of its occurrence is hard to estimate. Other open water macrophytes associated with *P. foliosus* were *P. natans* and *Chara* cf. *vulgaris.* Because Pondweeds are heavily consumed by waterfowl (Martin, 1951; Fassett, 1957), *P. foliosus* was most likely introduced into the study site by ducks or other waterfowl.

A third new record for the flora of Portsmouth, the adventive *Najas minor,* is also the first record for New Hampshire (Padgett and Crow, 1993). A European native, *Najas minor* (Eutrophic Water-nymph) was first reported in America in the Hudson River, in 1934 (Clausen, 1936). The North American range of this introduced species has continued to spread steadily in the eastern United States. By 1968, *N. minor* was known from New York, Pennsylvania, Illinois, West Virginia, Tennessee, Alabama and Florida (Merilainen, 1968). Its present North American distribution extends from New England and New York west to Illinois, south to Florida, Mississippi and Arkansas (Haynes, 1979; Crow and Hellquist, in press). The first report for this plant in New England was in 1965, occurring in Lake Champlain at New Haven, Vermont. Two reports of the species occurring in Bershire County, Massachusetts followed in 1974 (Hellquist, 1977). Hellquist and Crow (1980) report the distribution of *N. minor* to be infrequent in waters of extreme western New England. The present discovery of *N. minor* in New Hampshire possibly represents the northeastern-most range extension to date of the species for the U.S.

At the H.C.A. created wetland, *Najas minor* occurs in the open water areas. A component of the strictly aquatic macrophyte com-

munity of the site, *N. minor* is commonly associated with *Potamogeton pusillus, P. natans, Utricularia gibba* and *Chara* cf. *vulgaris* Later in the summer, many plants became fragmented and consequently were floating at the water surface and near the pool margins.

Najas minor is an annual, producing large quantities of seed. The most important dispersal agent for *N. minor* is waterfowl who feed heavily on the entire plant. Interestingly, the pattern of distribution of *N. minor* is very similar to the Atlantic flyway pattern of migrating waterfowl (Merilainen, 1968). Therefore it is believed that *N. minor* was probably introduced into the site by waterfowl. *Najas minor* has also been reported to invade recently constructed artificial lakes and ponds (Wentz and Stuckey, 1971).

FLORA OF H.C.A. PORTSMOUTH CREATED WETLAND

The vascular flora of the H.C.A. Portsmouth created wetland consists of 104 species, belonging to 69 genera and 45 families. Fifty-six species are dicots and forty-four species are monocots. The dominant families are the Asteraceae, Cyperaceae and Poaceae.

POLYPODIOPHYTA

DRYOPTERIDACEAE

Onoclea sensibilis L. Sensitive Fern

Abundant; throughout the wetland on wet soil. *Padgett 59, 145.*

OSMUNDACEAE

Osmunda regalis L. Royal Fern

Uncommon; on western edge of wetland growing on embankment. *Padgett 138.*

THELYPTERIDACEAE

Thelypteris palustris Schott Marsh Fern

Occasional; along the shores of the wetland but locally abundant along the western shore. *Padgett 92, 160, 231.*

EQUISETOPHYTA

EQUISETACEAE

Equisetum arvense L. Common Horsetail
Common; throughout the wetland on wet or moist soils. *Padgett 56, 81.*

MAGNOLIOPHYTA

DICOTYLEDONS

ACERACEAE

Acer rubrum L. Red Maple
Common; throughout the emergent wetland as seedlings, but more occasional as young trees. *Padgett 87.*

APIACEAE

Cicuta bulbifera L. Bulbiferous Water-hemlock
Common; throughout the wetland growing in emergent areas. *Padgett 68, 158, 183, 217.*

Sium suave Walter Water-parsnip
Uncommon; growing in wet emergent areas. *Padgett 216.*

AQUIFOLIACEAE

Ilex verticillata (L.) A. Gray Winterberry
Occasional; growing in wooded areas within the wetland. *Padgett 235.*

ASCLEPIADACEAE

Asclepias incarnata L. subsp. *pulcra* (Ehrh. ex. Willd.) Woodson Swamp Milkweed
Occasional; throughout the emergent wetland, but locally abundant in the western shore area. *Padgett 86, 121.*

ASTERACEAE

Aster lanceolatus var. *simplex* (Willd.) A. G. Jones Eastern Lined Aster
Uncommon; along western side of wetland. *Padgett 237.*

Aster racemosus Ell. Small White Aster
Uncommon; growing around the western shore area. *Padgett 252.*

Bidens connata Muhl. Purplestem Beggar-ticks
Ocassional; in emergent areas, but more common in the western area. *Padgett 218, 234, 245, 246, 253, 256, 261.*
Bidens frondosa L. Devil's Beggar-ticks
Uncommon; in emergent area of the western shore. *Padgett 233.*
Eupatorium perfoliatum L. Boneset
Occasional; growing along wet shores and emergent areas of the wetland. *Padgett 198.*
Euthamia graminifolia (L.) Nutt. Common Flat-topped Goldenrod
Occasional; growing along the shores of the wetland. *Padgett 222.*
Solidago rugosa Miller subsp. *rugosa* Wrinkle-leaved Goldenrod
Occasional; growing along the shores and scattered in the emergent areas. *Padgett 181.*

BALSAMINACEAE
Impatiens capensis Meerb. Orange Touch-me-not
Occasional; throughout the northern emergent areas and outermost shores. *Padgett 175.*

BETULACEAE
Alnus incana (L.) Moench. subsp. *rugosa* (Du Roi) Clausen Speckled Alder
Frequent; growing along outer shores and wooded areas. *Padgett 76, 101.*

CALLITRICHACEAE
Callitriche verna L. Water Starwort
Uncommon; growing in shallow water areas along the shores. *Padgett 58, 187.*

CLUSIACEAE
Hypericum boreale (Britt.) Bickn. St. John's-wort
Uncommon; growing in emergent marsh areas. *Padgett 228.*
Hypericum canadense L. Narrow-leaved St. John's-wort

Uncommon; growing in emergent marsh areas. *Padgett 204.*

Hypericum dissimulatum Bickn. St. John's-wort

Locally abundant; in western open marsh area and along northwestern shore. *Padgett 227.*

Hypericum ellipticum Hook. St. John's-wort

Common; throughout the emergent areas and in shallow water. *Padgett 139, 156.*

Hypericum mutilum L. Dwarf St. John's-wort

Occasional; throughout the emergent marsh. *Padgett 201.*

Triadenum fraseri (Spach) Gleason Marsh St. John's-wort

Common; throughout the emergent areas but more frequent in the open area of the western side. *Padgett 94, 146, 195, 260.*

CORNACEAE

Cornus amomum subsp. *obliqua* (Raf.) J. S. Wilson Silky Dogwood

Uncommon; growing along outer southwestern shore. *Padgett 104.*

Cornus stolonifera Michx. Red-stemmed Dogwood

Occasional; growing in emergent and wooded areas, but more common in the western open marsh area. *Padgett 89, 151.*

DROSERACEAE

Drosera intermedia Hayne Sundew

Locally abundant; growing in wet open area of western side of the wetland. *Padgett 95, 147.*

ERICACEAE

Lyonia ligustrina (L.) DC. Maleberry

Occasional; in wooded areas throughout the wetland. *Padgett 230.*

Vaccinium corymbosum L. Highbush Blueberry

Uncommon; in wooded areas on western side of wetland. *Padgett 155.*

Vaccinium macrocarpon Aiton Cranberry

Locally abundant; in open area of western shore and grow-

ing with *Typha latifolia* in northern area of wetland. *Padgett 90, 140.*

HALORAGACEAE

Proserpinaca palustris L. Common Mermaid-weed

Uncommon; in open water areas close to the shores. *Padgett 69, 125.*

LAMIACEAE

Lycopus americanus Muhl. Bugle-weed

Occasional; throughout the emergent marsh. *Padgett 205.*

Lycopus uniflorus Michx. Bugle-weed

Common; throughout the emergent marsh. *Padgett 240.*

Scutellaria galericulata L. Common Scullcap

Uncommon; growing in wet mud of northwestern shore. *Padgett 208.*

LENTIBULARIACEAE

Utricularia gibba L. Creeping Bladderwort

Abundant; in open water areas throughout the wetland. *Padgett 57, 133.*

Utricularia minor L. Lesser Bladderwort

Uncommon; growing in very shallow pools floating on surface between other vegetation. *Padgett 250.*

LYTHRACEAE

Lythrum salicaria L. Purple Loosestrife

Common; throughout the emergent marsh areas. *Padgett 75, 114, 124.*

MYRICACEAE

Myrica gale L. Sweet Gale

Uncommon; in emergent wetland at island shore edge of northern area. *Padgett 191.*

NYMPHAEACEAE

Nuphar variegata Durand Yellow Water-lily

Occasional; in open water areas close to shores. *Padgett 126.*

ONAGRACEAE

Epilobium palustre L. Marsh Willow-herb

Uncommon; growing in emergent marsh areas. *Padgett 221.*

Ludwigia palustre (L.) Elliott. Common Water-purslane

Frequent; growing throughout the open water areas and on the muddy bottoms of the emergent areas. *Padgett 63, 129.*

POLYGONACEAE

Polygonum amphibium L. var. *emersum* Michx. Water Smartweed

Common; throughout the marsh on the elevated islands and emergent areas. *Padgett 148, 180, 238, 247.*

Polygonum arifolium L. Tearthumb

Occasional; growing with *Polygonum sagittatum. Padgett 193.*

Polygonum lapathifolium L. Pale Smartweed

Uncommon; growing on a beaver den in northern area. *Padgett 172.*

Polygonum punctatum Ell. var. *punctatum* Water Smartweed

Frequent; throughout the open emergent wetland. *Padgett 186, 190.*

Polygonum sagittatum L. Arrow-vine

Common; at the edges of the open water areas. *Padgett 179, 185.*

Rumex crispus L. Curly Dock

Uncommon; at the northern edge of the wetland. *Padgett 177.*

PRIMULACEAE

Lysimachia terrestris (L.) BSP. Bulbil-loosestrife

Frequent; throughout the emergent wetland. *Padgett 152, 219, 239, 242.*

ROSACEAE

Spiraea latifolia (Aiton) Borkh. Meadowsweet

Uncommon; throughout emergent areas of the wetland. *Padgett 85.*

Spiraea tomentosa L. Hardhack

Common; throughout emergent areas, but more frequent in open western area. *Padgett 91, 137.*

RUBIACEAE

Galium palustre L. Marsh Bedstraw

Common; growing in the lower parts of the emergent vegetation throughout the wetland. *Padgett 83.*

SALICACEAE

Salix nigra Marshall Black Willow

Uncommon; growing along the northern and western outer shores. *Padgett 200.*

SAXIFRAGACEAE

Penthorum sedoides L. Ditch-stonecrop

Occasional; growing in open emergent areas and cattail stands of western side of wetland. *Padgett 207.*

SCROPHULARIACEAE

Agalinis purpurea (L.) Pennell Purple Gerardia

Uncommon; growing in marsh area along the western limits of the wetland. *Padgett 214.*

Mimulus ringens L. Monkey Flower

Occasional; growing in emergent marsh areas throughout the northern half of the wetland. *Padgett 165, 178.*

SOLANACEAE

Solanum dulcamara L. Bittersweet

Occasional; throughout the emergent wetland. *Padgett 62, 113.*

URTICACEAE

Boehmeria cylindrica (L.) Sw. Bog Hemp

Uncommon; growing along outer edge of wetland in northwest area. *Padgett 257.*

VERBENACEAE

Verbena hastata L. Blue Vervain

Uncommon; growing along the outer edges of the wetland. *Padgett 203.*

VIOLACEAE

Viola lanceolata L. Strap-leaved Violet

Locally abundant; growing in moist soil of western open marsh area. *Padgett 255.*

Monocotyledons

ALISMATACEAE

Alisma triviale Pursh. Northern Water-plantain

Occasional; growing in muddy substrate throughout the wetland. *Padgett 96, 166.*

Sagittaria latifolia Willd. Common Arrow-head

Occasional; in shallow water at southwest end of wetland. *Padgett 97, 176.*

CYPERACEAE

Carex comosa Boott Long-hair Sedge

Common; throughout the emergent areas of the wetland. *Padgett 67, 107, 144.*

Carex lurida Wahl. Lurid Sedge

Common; Throughout the emergent areas of the wetland. *Padgett 98, 168.*

Carex lupulina Willd. Hop Sedge

Uncommon; in emergent area along western perimeter. *Padgett 258.*

Carex pseudocyperus L. Cyperus-like Sedge

Common; throughout the emergent areas of the wetland. *Padgett 132.*

Carex scoparia Schk. Broom Sedge

Frequent; throughout the emergent areas of the wetland. *Padgett 70, 109.*

Carex stricta Lam. Tussock Sedge

Occasional; along the outer shore edges and emergent marsh areas. *Padgett 72.*

Carex vulpinoidea Michx. Fox Sedge

Frequent; throughout the emergent areas of the wetland. *Padgett 143, 154.*

Cyperus strigosus L. Umbrella Sedge

Uncommon; growing along western and northern shores. *Padgett 196.*

Dulichium arundinaceum (L.) Britt. Three-way Sedge

Locally abundant; growing in open marsh area of western shore. *Padgett 215.*

Eleocharis acicularis (L.) R.&S. Needle-rush

Common; growing along muddy shores and throughout the emergent marsh. *Padgett 99, 173.*

Eleocharis obtusa (Willd.) Shultes Blunt Spike-rush

Common; growing throughout emergent marsh areas and shallow pools. *Padgett 169.*

Eleocharis smallii Britt. Small's Spike-rush

Occasional; throughout the emergent areas, but more locally abundant growing out of shallow pools of western half of wetland. *Padgett 73.*

Eleocharis tenuis (Willd.) Shultes var. *tenuis* Slender Spike-rush

Occasional; in wet mud open areas or below *Typha latifolia* stands. *Padgett 170.*

Rhynchospora capitellata (Michx.) Vahl. Beakrush

Uncommon; growing in wooded area of northwestern region of wetland. *Padgett 226.*

Scirpus atrocinctus Fern. Black-girdle Bulrush

Uncommon; growing along northern and southern outer limits of wetland. *Padgett 159.*

Scirpus cyperinus (L.) Kunth. Wool Grass

Frequent; Growing in emergent areas throughout the wetland. *Padgett 161, 189.*

Scirpus hattorianus Makino

Uncommon; growing along outer limits of the wetland. *Padgett 150, 225.*

Scirpus pungens Vahl. Three-square Bulrush

Uncommon; growing in wet soil along the northwestern shore. *Padgett 194.*

Scirpus tabernaemontanii K.C. Gmel. (= *S. validus* Vahl) Great Soft-stem Bulrush

Frequent; throughout the emergent wetland. *Padgett 112, 122.*

IRIDACEAE

Iris versicolor L. Northern Blue Flag

Uncommon; growing along the edges of open pools around the islands. *Padgett 115, 136.*

JUNCACEAE

Juncus articulatus L. Jointed Rush

Frequent; throughout the emergent wetland. *Padgett 131, 135, 163, 171, 188.*

Juncus canadensis J. Gay Canada Rush

Occasional; throughout the emergent wetland. *Padgett 223, 224.*

Juncus effusus L. Soft Rush

Abundant; throughout the emergent wetland. *Padgett 66, 80, 111, 117.*

LEMNACEAE

Lemna minor L. Common Duckweed

Abundant; floating on surface throughout the open water and *Typha* stands. *Padgett 116.*

Wolffia columbiana Karst. Water-meal

Uncommon; floating on surface in open water with *Lemna minor* at north end of study site. Site Record.

NAJADACEAE

Najas minor Allioni. Eutrophic Water-nymph

Common; in open water with *Chara* cf. *vulgaris Padgett 167, 236.*

POACEAE

Calamagrostis canadensis (Michx.) Beauv. Reed Bent Grass

Common; in emergent areas around the perimeter of the wetland. *Padgett 120, 153, 251.*

Echinochloa crusgalli (L) Beauv. Barnyard Grass

Uncommon; in emergent marsh areas. *Padgett 213, 248.*

Glyceria canadensis (Michx.) Trin. Rattlesnake Manna Grass

Uncommon; along outer edge of the western shore. *Padgett 259.*

Leersia oryzoides (L.) Sw var. *oryzoides* Rice Cut Grass
Common; in emergent marsh areas. *Padgett 241, 249.*
Panicum villosissimum Nash. Panic Grass
Uncommon; growing in open areas adjacent with upland islands. *Padgett 192.*
Panicum rigidulum Nees. Panic Grass
Uncommon; in emergent marsh areas. *Padgett 244.*
Phalaris arundinacea L. Reed Canary Grass
Frequent; growing along the outer edges of the wetland. *Padgett 60, 65, 93, 108, 119, 162.*
Poa palustris L. Fowl Bluegrass
Occasional; in open marsh areas. *Padgett 174.*

PONTEDERIACEAE
Pontederia cordata L. Pickerel-weed
Occasional; in shallow open water areas close to the shore, forming dense stands. *Padgett 102, 123.*

POTAMOGETONACEAE
Potamogeton amplifolius Tuckerman Big-leaf Pondweed
Uncommon; in open water area with *Potamogeton natans* at southeast end of wetland. *Padgett 127.*
Potamogeton foliosus Raf. var. *foliosus* Leafy Pondweed
Frequent; in open water areas throughout the wetland. *Padgett 164.*
Potamogeton natans L. Floating Pondweed
Abundant; throughout open water areas. *Padgett 57, 74, 130.*
Potamogeton pusillus L. var. *tenuissimus* Mert. and Koch Slender Pondweed
Frequent; in open water areas throughout the wetland. *Padgett 118, 128.*

SPARGANIACEAE
Sparganium eurycarpum Engelm. Giant Bur-reed
Common; in shallow water areas throughout the marsh, but more frequent along the western edge of the wetland. *Padgett 53, 88.*

TYPHACEAE

Typha angustifolia L. Narrow leaved Cattail

Occasional; growing intermixed with *Typha latifolia* along pool edges and in thick stands. *Padgett 77, 142.*

Typha latifolia L. Common Cattail

Abundant; throughout the wetland, often encroaching the open pools. *Padgett 78.*

In conclusion, the vegetation component of this relatively young created wetland appears to be quite heterogeneous with a diverse floristic composition comprising seven discernible vegetation cover types. One hundred and four vascular plant species are documented from the wetland including two species listed as rare for New Hampshire and the first state record for an introduced weedy species. What makes this site remarkable is that although it is floristically diverse there was no direct planting of wetland plants during its construction. The challenge of establishing diverse, functional wetland plant communities at this site appears to have been met essentially by the transplantation of wetland muck. This point should be stressed for future considerations in mitigation project planning.

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